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Stand Estimates of Biomass and Growth in Pinyon-Juniper Woodlands in Nevada

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ABSTRACT

Regression equations for estimating overstory biomass, fuelwood, and growth in pinyon-juniper stands are presented. Input variables are canopy cover and weighted mean height, stem diameter, crown diameter, and radial growth. Point sampling techniques for evaluating the input variables are described.

KEYWORDS: pinyon, juniper, biomass, growth, sampling methods, regression models.

Meeuwig and Budy (1981) described procedures for estimating various biomass components and growth rates in pinyon-juniper stands using point and line-intersect sampling. These procedures are much more efficient than fixed-size-plot sampling, but their theoretical basis is not readily comprehended. The purpose of this paper is to present a point sampling method for estimating overstory biomass, fuelwood, and growth that is simpler and more easily understood.

In this method, individual tree estimates are not made. Instead, the estimates are made on a stand basis, using canopy cover, mean tree height, mean diameter of stems, mean diameter of crowns, and mean width of growth rings.

All measurements and estimates in this paper apply only to singleleaf pinyon (*Pinus monophylla*) and to Utah juniper (*Juniperus osteosperma*) trees at least 10 feet (3 m) tall. Trees less than 10 feet tall are considered understory and are excluded along with such associated woody species as curlleaf mountain mahogany (*Cercocarpus ledifolius*).

EQUATIONS

The regression equations for these stand estimates were derived from data collected in 114 stands across Nevada and in adjacent portions of California and Utah. Line-intersect sampling procedures, essentially the same as those described by

Meeuwig and Budy (1981), were used in 103 stands to estimate overstory biomass, fuelwood, and growth rates. Each stand was sampled with a set of parallel lines, 98.4 feet (30 m) long and 19.7 feet (6 m) apart. Six lines were used in most stands but high-density stands were sampled with four or five lines and low-density stands were sampled with seven or eight lines. The other 11 stands were sampled with a 30 m by 30 m plot on which all trees were measured and overstory biomass, fuelwood, and growth rates were estimated with regression equations (Meeuwig 1979).

Overstory biomass is total oven-dry weight per unit area of trees above stump height (6 inches or 15 cm). Fuelwood is all stems and branches larger than 3 inches (7.6 cm) diameter outside bark. Their equations in U.S. units are:

$$\hat{T} = (13.04 \cdot \bar{D} - 9.585 \cdot \bar{H} + 76.64 \cdot \bar{D} \cdot \bar{H} \cdot \bar{C}) \cdot \text{Cov} + (56.37 \cdot \bar{C}_j - 88.83 \cdot \bar{D}_j) \cdot \text{JCov} + 1158$$

$$\hat{W} = (6.826 \cdot \bar{D} \cdot \bar{H} - 22.84 \cdot \bar{D} - 1.681 \cdot \bar{H} \cdot \bar{C} - 0.09752 \cdot \bar{D} \cdot \bar{H} \cdot \bar{C}) \cdot \text{Cov} + (44.92 \cdot \bar{C}_j - 67.53 \cdot \bar{D}_j) \cdot \text{JCov} + 177$$

where:

\hat{T} is estimated overstory biomass (oven-dry pounds per acre)

\hat{W} is estimated fuelwood (oven-dry pounds per acre)

\bar{D} is weighted mean stem diameter at stump height (inches)

\bar{H} is weighted mean tree height (feet)

\bar{C} is weighted mean crown diameter (feet)

Cov is canopy cover (percent)

\bar{C}_j is weighted mean crown diameter of juniper trees only

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\bar{D}_j is weighted mean stem diameter (stump height)
of juniper trees
 $JCov$ is canopy cover of juniper trees (percent).

Stem diameter, height, and crown diameter are all means weighted by crown area. \bar{D} , \bar{H} , \bar{C} , and Cov are for both pinyon and juniper, but \bar{D}_j , \bar{C}_j , and $JCov$ are for juniper only and serve as corrections for variations in species composition.

The overstory biomass equation has an R^2 of 0.993 and a standard error of estimate of 1,918 pounds per acre (2 150 kg per ha) or 2.7 percent of the mean of \hat{T} . The fuelwood equation has an R^2 of 0.990 and a standard error of estimate of 1,422 pounds per acre (1 594 kg per ha) or 4.6 percent of the mean of \hat{W} .

The equations for estimating overstory biomass growth ($\Delta\hat{T}$) and fuelwood growth ($\Delta\hat{W}$) in pounds per acre per year are:

$$\Delta\hat{T} = (17.54 - 1.745\bar{D} + 15.76\bar{H}\bar{C} + 2.376\bar{D}\bar{H}\bar{C})\bar{R}Cov + 19.78\bar{R}_jJCov + 69$$

$$\Delta\hat{W} = (3.118\bar{C} - 5.910\bar{D} - 2.067\bar{H} + 5.210\bar{D}\bar{H}\bar{C})\bar{R}Cov + 0.4116\bar{D}Cov - 0.2013\bar{D}_jJCov - 8$$

\bar{R} is weighted mean width of the 10 outermost complete annual rings (inches per 10 years) of pinyon and juniper trees at least 10 feet (3 m) tall. \bar{R}_j is weighted mean width of the 10 outermost complete annual rings of juniper trees only. \bar{R} and \bar{R}_j are weighted by crown area just as \bar{D} , \bar{H} , \bar{C} , \bar{D}_j , and \bar{H}_j are.

The biomass growth equation has an R^2 of 0.991 and its standard error of estimate is 32 pounds per acre (36 kg per ha) per year or 4.1 percent of the mean value of $\Delta\hat{T}$. The fuelwood growth equation has an R^2 of 0.984 and its standard error of estimate is 24 pounds per acre (27 kg per ha) per year or 4.8 percent of the mean value of $\Delta\hat{W}$.

The metric equivalents of the regression equations are:

$$\hat{T} = (5.756\bar{D} - 35.25\bar{H} + 33.82\bar{D}\bar{H}\bar{C})Cov + (207.3\bar{C}_j - 39.20\bar{D}_j)JCov + 1298$$

$$\hat{W} = (9.883\bar{D}\bar{H} - 10.08\bar{D} - 20.28\bar{H}\bar{C} - 0.4632\bar{D}\bar{H}\bar{C})Cov + (165.2\bar{C}_j - 29.80\bar{D}_j)JCov + 198$$

$$\Delta\hat{T} = (7.738 - 0.3031\bar{D} + 6.956\bar{H}\bar{C} + 0.4127\bar{D}\bar{H}\bar{C})\bar{R}Cov + 8.727\bar{R}_jJCov + 77$$

$$\Delta\hat{W} = (4.514\bar{C} - 1.027\bar{D} - 2.993\bar{H} + 0.9052\bar{D}\bar{H}\bar{C})\bar{R}Cov + 0.1816\bar{D}Cov - 0.0882\bar{D}_jJCov - 9$$

\bar{D} is in centimeters, \bar{H} and \bar{C} are in meters, \bar{R} is centimeters per 10 years, \hat{T} and \hat{W} are kilograms per hectare, and $\Delta\hat{T}$ and $\Delta\hat{W}$ are kilograms per hectare per year.

POINT SAMPLING PROCEDURE

The stand parameters required for input into the regression equations can be determined in a number of ways: fixed-size-plot, line-intersect, or point sampling. A method that samples in proportion to crown area, the simplest and most efficient approach, will be described.

A grid of points is laid out in the stand to be sampled. Species, stump height diameter, height, and average crown diameter are tallied for each tree whose crown is over a sample point. If growth is to be estimated, radial growth of the tallied trees is also measured. If a point falls under the overlapping crowns of two trees, both are tallied. Only pinyon and juniper at least 10 feet tall are tallied. Daubenmire's (1959) criteria are followed in defining crown coverage. Each crown is considered a polygon of lines connecting the branch ends around the tree. Gaps between branches are considered part of the crown.

Since sampling probability of each tree in the stand is proportional to its crown area, the means of stump diameter, height, crown diameter, and radial growth are automatically weighted by crown area. The stand parameters are calculated as follows:

$$Cov = \frac{n}{N} \times 100$$

$$JCov = \frac{n_j}{N} \times 100$$

$$\bar{D} = \frac{\sum D}{n}$$

$$\bar{D}_j = \frac{\sum D_j}{n_j}$$

$$\bar{H} = \frac{\sum H}{n}$$

$$\bar{C} = \frac{\sum C}{n}$$

$$\bar{C}_j = \frac{\sum C_j}{n_j}$$

$$\bar{R} = \frac{\sum R}{n}$$

$$\bar{R}_j = \frac{\sum R_j}{n_j}$$

where:

N is the number of sample points

n is the number of tallied pinyons and junipers

n_j is the number of tallied junipers

D , H , C and R are the tallied tree measurements, both species

D_j , C_j , and R_j are tallied juniper measurements.

As an example, let us assume a stand is sampled with a grid of 20 points and that six pinyon and two junipers are tallied. \bar{D} is 14.8 inches (37.6 cm), \bar{H} is 17.3 feet (5.27 m), \bar{C} is 15.1 feet (4.60 m), \bar{D}_j is 27.1 inches (68.8 cm), \bar{C}_j is 27.4 feet (8.35 m), \bar{R} is 0.19 inches (0.48 cm) per decade, and \bar{R}_j is 0.16 inches (0.41 cm) per decade.

Total cover is 40 percent and juniper cover is 10 percent. Estimated biomass (\hat{T}) is 45,600 pounds per acre (51 100 kg per ha), according to the regression equation. Estimated fuelwood (\hat{W}) is 17,900 pounds per acre (20 100 kg per ha). This is equivalent to about 9 cords per acre, since the oven-dry weight of one cord is about 1 ton. Estimated biomass growth ($\Delta\hat{T}$) is 481 pounds per acre (538 kg per ha) per year and estimated fuelwood growth ($\Delta\hat{W}$) is 274 pounds per acre (307 kg per ha) per year.

MEASUREMENTS

Stem diameter outside bark (D) is measured or estimated to the nearest inch at stump height (6 inches or 15 cm above the soil surface). For trees with more than one stem at stump height, D is the diameter of a circle having the same area as the

combined cross-sectional areas of the stems, or the square root of the sum of squared diameters of the individual stems:

$$D = \sqrt{D_1^2 + D_2^2 + \dots D_n^2}$$

Tree height (H) and average crown diameter (C) are measured or estimated to the nearest foot. Average crown diameter is the diameter of a circle having the same area as the projected area of the tree crown. It is approximated by the square root of the length of the widest axis (Cx) of the crown times the width perpendicular (Cy) to the widest axis:

$$C = \sqrt{Cx \cdot Cy}$$

If estimates of growth are desired, radial growth must be measured. Radial growth (R) is the combined thickness of the 10 outermost complete annual rings, measured to the nearest 0.05 inch (or the nearest 0.1 cm) on increment cores taken at stump height. An increment hammer is faster and usually produces a better core than an increment borer in pinyon and juniper. Two cores from opposite sides of the stem are usually sufficient on trees with reasonably round stems up to 16 inches (40 cm) diameter at stump height. Four cores should be taken about 90 degrees apart on larger trees and on trees with badly out-of-round stems.

For trees with more than one stem at stump height, the increment cores are taken on the largest stem. Equivalent radial growth (R) is calculated by multiplying the measured thickness of the 10 annual rings (R_1) by the calculated equivalent diameter (D) and dividing by the diameter (D_1) of the stem from which the cores were taken:

$$R = R_1 \cdot D / D_1$$

It is often difficult to determine stem diameter and to obtain representative increment cores at the stump height on junipers. In many cases, it is more convenient and accurate to determine stem diameter (Dbh) and radial growth (Rbh) at breast height (4.5 feet or 1.37 m) and correct to Dj and Rj at stump height by:

$$\begin{aligned} Dj &= 1.3 \cdot Dbh + 2.2 \\ Rj &= 1.3 \cdot Rbh \end{aligned}$$

These equations apply to measurements in inches. If measurements are in centimeters the equations are the same except the intercept in the first equation is 5.6 instead of 2.2.

SAMPLING DESIGN

Stratification of the stands and the physical layout of the sampling points depend on the characteristics of the area to be inventoried and the preferences of the designer. The number of sampling points required depends on the variability and the allowable sampling error in each stratum.

We suggest that each stratum be sampled with at least three sampling units with 20 sampling points in each unit. Each sampling unit provides an estimate of biomass and fuelwood in pounds per acre. The coefficient of variation of these estimates can be used to calculate the number of additional sampling units, if any, required to be within the allowable limit. A shortcut method for determining sample size is described by Meeuwig and Budy (1981).

A MODIFIED PROCEDURE

The following variation of the point sampling procedure is more efficient than the one just described because it requires only one-fourth as many points to obtain the same intensity of sampling. In addition to trees with crowns over the sampling point, trees are tallied if their crowns are within one-half of their average crown diameter of the sampling point. This variation increases the probability of any particular tree being tallied at a random sample point by a factor of four.

Use of this variation requires only a minor change in calculation procedures. The regression equations and the calculation of mean height, stump diameter, crown diameter, and radial growth remain the same. The only difference is in the calculation of canopy cover percentage:

$$Cov = \frac{n}{4 \cdot N} \times 100$$

$$JCov = \frac{nj}{4 \cdot N} \times 100$$

The extra time required to measure the crown diameter of the occasional borderline tree and its distance from the sampling point is more than offset by the time saved by using only one quarter as many sampling points. The suggested number of points in a sampling unit can be reduced from 20 to 5. Five points with the modified procedure will, on the average, result in as many trees being tallied as 20 points will with the simple procedure.

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